Has the QCD critical point been observed at RHIC? - A Rebuttal

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This note rebuts an old but recurring claim by Antoniou, Davis and Diakonos [1], that the critical point and associated critical exponents reported in Ref. [2], is based on an erroneous treatment of scaling relations near the critical point.

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As indicated in Ref. [2], we exploit the phenomenology of thermal models to establish the chemical freeze-out region (assumed to be close to the coexistence region), and associate the combinations of freeze out temperature and baryon chemical potential (T, μ_B) with the values for $\sqrt{s_{NN}}$ [see for example, Refs. [3–5]]. This means that;

- $\sqrt{s_{NN}}$ is used as a control parameter to measure the "distance" $\tau_{\sqrt{s}}$ to the CEP, where $\tau_{\sqrt{s}} = (\sqrt{s_{NN}} - \sqrt{s_{NN}}^{\rm cep})/\sqrt{s_{NN}}^{\rm cep}$. Here it is important to emphasize that Finite Size Scaling is a very general and flexible technique that does not require precise nor detailed information about the direction of approach to the CEP in the (T, μ_B)-plane. A variable that can give a reasonable measure of the distance to the CEP will suffice.

- Our Finite Size Scaling analysis is actually performed for fixed values of T (and μ_B) at each collision energy. This is validated by recent extractions of T and μ_B (at chemical freeze out) as a function of collision centrality or system size (see Fig.1) [6]. Thus, the relevant critical exponent in our Finite Size Scaling analysis is γ, **not** α, as claimed by the authors of Ref. [1]. Note as well, that for isothermal freeze out, the isentropic compressibility κ_S can be expressed in terms of the isothermal compressibility κ_T and the ratio C_P/C_V of the constant pressure (P) and constant volume (V) heat capacities (C).

Our Finite-Size Scaling analysis is further validated in Fig. 5 of Ref. [2], where it is shown that the extracted critical exponents, coupled with the estimated location of the CEP (T^{cep} and μ_B^{cep}) , **do** result in the requisite collapse of the full data set on to a single curve or *scaling function*. This constitutes a crucial and compelling "closure" test of the efficacy of our Finite Size Scaling analysis and the associated parameters extracted. Incidentally, the estimates given for the CEP and the critical exponents in Ref. [2] have been recently validated [7] with a different set of observables.

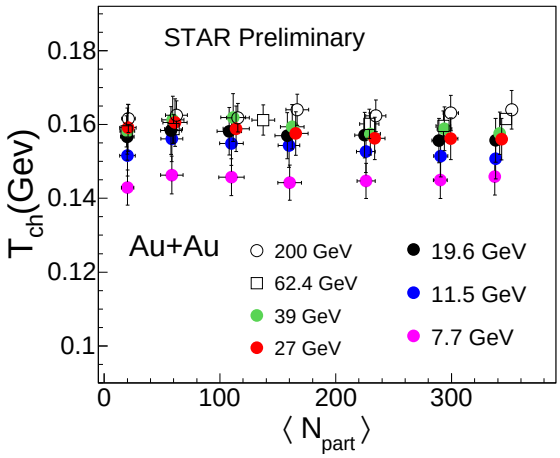

FIG. 1. Chemical freeze out temperature vs. $\langle N_{\rm part}\rangle$ or collision centrality [6].

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